433-SPEC-0003

GAMMA-RAY LARGE AREA SPACE TELESCOPE (GLAST) PROJECT

SPACECRAFT PERFORMANCE SPECIFICATION

APRIL 24, 2002

GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

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NASA Goddard Space Flight Center

Greenbelt, Maryland

GLAST PROJECT SPACECRAFT PERFORMANCE SPECIFICATION

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Acronyms

API	Application Programming Interface
b	bit
B	Byte
BER	Bit Error Rate
C&DH	Command and Data Handling
CCSDS	Consultative Committee for Space Data Systems
CG	Center of Gravity
COP	Command Operation Procedure
dB	Decibel
DEG	Degree
DL	Downlink
EEPROM	Electrically Erasable Programmable Read Only Memory
EMI	Electromagnetic Interference
FSW	Flight Software
Gb	Gigabit
GBM	GLAST Burst Monitor
GLAST	Gamma ray Large Area Space Telescope
GN	Ground Network
GNC	Guidance Navigation & Control
GPS	Global Positioning System
GSE	Ground Support Equipment
Hz	Hertz
ICD	Interface Control Document CH-03
IPV	Individual Pressure Vessel
IRD	Interface Requirements Document
LAT	Large Area Telescope
MB	Megabyte
MSS	Mission System Specification
NTIA	National Telecommunications and Information Administration
PB	Playback
RF	Radio Frequency
RT	Real Time
SC	Spacecraft
SN	Space Network
SSR	Solid State Recorder
TBD	To Be Determined
TBS	To Be Supplied
TBR	To Be Resolved
TDRSS	Tracking and Data Relay Satellite System
UL	Uplink
USN	Universal Space Network
VCDU	Virtual Channel Data Unit

1 Introduction

This specification provides the functionalities and the key performance requirements for the GLAST spacecraft.

The top level requirements in this specification flow down from the Mission System Specification (MSS), which contains the system-level requirements on the GLAST Observatory.

Instrument interfaces for the spacecraft are defined in two separate documents. There is one Interface Requirements Document (IRD) for the Large Area Telescope (LAT) instrument, and one for the GLAST Burst Monitor (GBM) instrument.

1.1 Spacecraft System

The spacecraft consists of all components needed to satisfy the requirements in this document. Together, the spacecraft and the science instruments make up the GLAST observatory.

1.2 System Description

A functional block diagram of the spacecraft is shown in Figure 1-1.

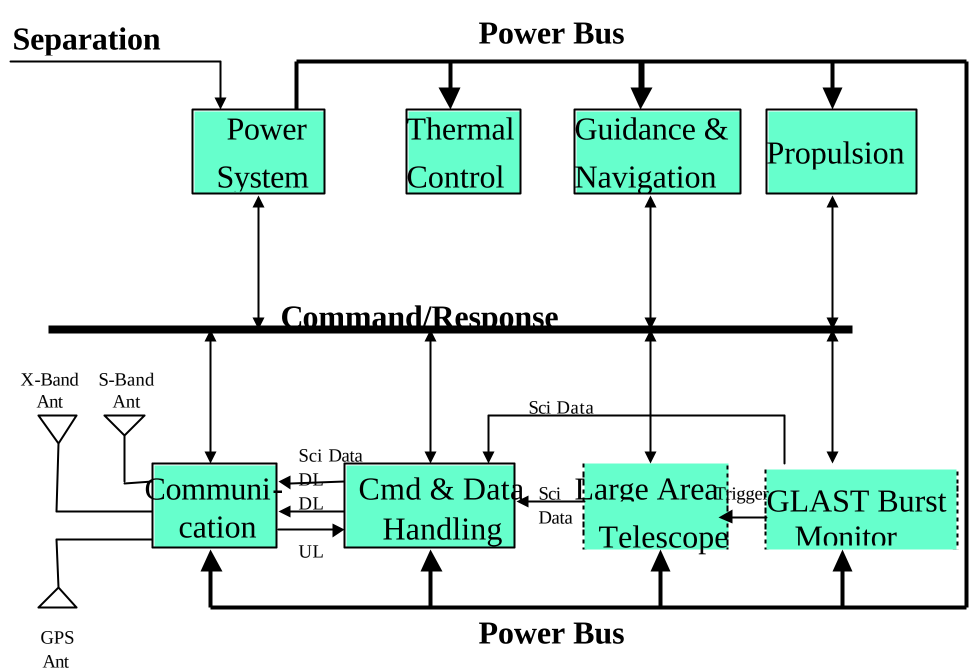

Figure 1-1 Conceptual Functional Block Diagram of the Spacecraft

There are some underlying components that do not appear on the functional diagram, viz., structure and flight software. The instruments are not part of the spacecraft system, although they are shown on the diagram to complete the set of components receiving spacecraft services.

For the purposes of this specification, the following functional description is assumed. The spacecraft designer shall develop a detailed description of the spacecraft subsystems and allocate the top level and derived requirements among the subsystems.

The mechanical subsystem provides a mounting platform for all spacecraft components and science instruments. It is also responsible for providing clear fields of view and for maintaining alignment, required by the science instruments and some spacecraft component.

The power subsystem converts solar energy to electrical energy, stores, and regulates it for the operation of spacecraft and instrument components. It includes solar arrays, batteries, battery charge control and conditioning circuitry, power regulation electronics, and instrumentation for monitoring state of charge, temperatures, etc. Power distribution includes the generation of the different power buses that are needed and the distribution of various services.

The electrical subsystem provides the harness and wiring necessary to provide power, command and telemetry functions. It also includes fault isolation (fuses, circuit breakers, diodes, etc.). In addition, it includes pyrotechnic devices, grounding, shielding, and EMI functions.

The thermal control subsystem maintains the spacecraft component temperatures within safe operating and non-operating ranges. It also maintains interface temperatures for the instruments, and it may be called upon to shed a portion of the instrument heat load. Thermal control includes heaters, thermostats, certain temperature sensors, heat pipes, radiating surfaces, insulation, and thermal isolators, as needed to control the temperatures of the various spacecraft components and instrument interfaces.

The Guidance Navigation & Control (GNC) subsystem executes the observing control modes of the observatory and provides a safe mode. The GNC subsystem includes all of the sensors and actuators that are needed to maintain control authority in all modes. This subsystem is self-monitoring and has the capability for detecting and correcting faults within the control system. The GNC subsystem also performs orbit determination on-board from GPS position data.
The GNC subsystem includes a propulsion subsystem with sufficient propellant to accomplish de-orbit for safe ocean disposal.

The Command and Data Handling (C&DH) subsystem distributes commands to and receives data from spacecraft components and science instruments via a MIL-STD 1553B bus. The C&DH subsystem interfaces with the S-band communications system for command uplinks and telemetry downlinks. In addition, the C&DH subsystem provides a dedicated interface to the LAT and GBM instruments for receiving science data. The C&DH subsystem provides bulk data storage for this data, which is output via a high rate interface with the communications subsystem. The C&DH subsystem also provides discrete services for control and monitoring of the instruments independent of the 1553 command and telemetry bus.

The spacecraft software subsystem implements functions such as attitude control, tracking and navigation, propulsion control, solar array pointing, and possibly antenna pointing. Communications from GBM to LAT, alert messages to ground, and pointing requests from the ground or LAT are spacecraft software controlled operations. In addition, software handles command processing and distribution as well as telemetry acquisition, processing and distribution throughout the spacecraft and between the spacecraft and the instruments.

The communications subsystem provides omni-directional communications for S-band traffic, which may flow through TDRSS as well as through a ground station. Alert messages travel bi-directionally through TDRSS, using its demand access service. The high-rate science data is downlinked via an X-band link to a ground station.

1.3 System Interfaces

System interfaces for the spacecraft are shown in Figure 1-2. These are the external interfaces for the spacecraft that are specified in different interface specification documents. Figure 1-2 only illustrates the interfaces and is not intended to illustrate data flow. The builder of the spacecraft will specify internal interfaces between spacecraft subsystems, as well as those between the spacecraft and its GSE.

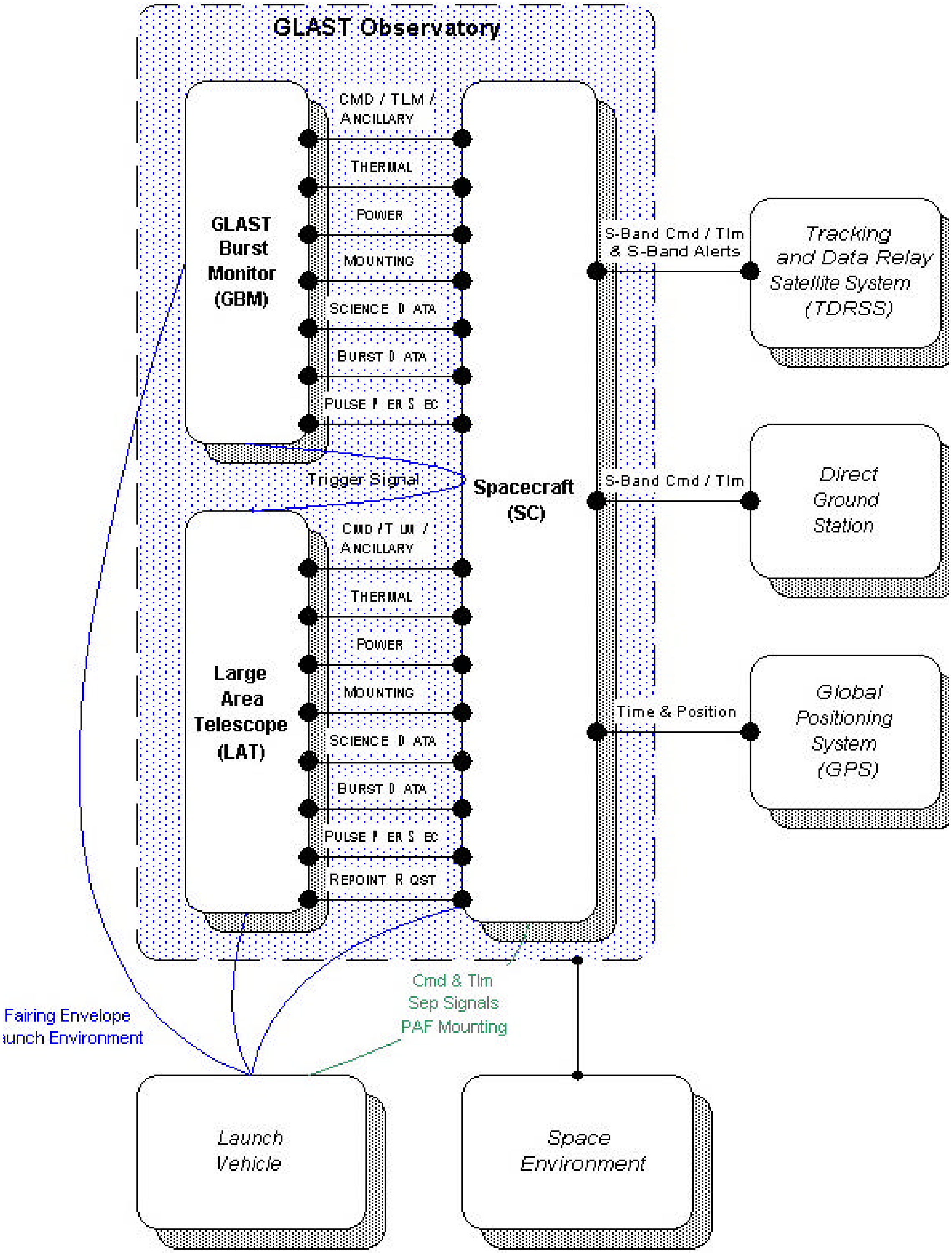

Figure 1-2 Spacecraft Interfaces

2 Applicable and Reference Documents

2.1 Applicable Documents

The following documents contain requirements that are invoked by this Spacecraft Performance Specification.

433-SRD-0001, GLAST Science Requirements Document

433-SPEC-0001, GLAST Mission System Specification

433-IRD-0001, GLAST LAT-SC Interface Requirements Document

433-IRD-0002, GLAST GBM-SC Interface Requirements Document

433-MAR-0003, GLAST Spacecraft Mission Assurance Requirements

433-RQMT-0005, GLAST Electromagnetic (EMI) Requirements Document

GEVS-SE Rev A, General Environmental Verification Specification for STS & ELV Payloads, Subsystems, and Components, June 1996. http://arioch.gsfc.nasa.gov/302/gevs-se/toc.htm

Mil-STD-1553B, Aircraft Internal Time Division Command/Response Multiplex Data Bus, 21 September, 1978

NTIA S/N: 903-008-0025-3, Manual of Regulations and Procedures for Federal Radio Frequency Management, January 2000, revision September 2001.

ANSI, AIAA G-020-1992 Guide for Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems.

NPD 8010.2C, NASA Policy Directive, Use of the Metric System of Measurement in NASA Programs, July 2000.

Delta II Payload Planners Guide, MDC 00H0016, October 2000.
http://www.boeing.com/defense-space/space/delta/docs/DELTA_II_PPG_2000.PDF

2.2 Reference Documents

The following document is for reference only.

433-OPS-0001, Operations Concept Document

3 Requirements

The primary requirement for the spacecraft bus is to provide host services for the scientific instruments and for its own subsystems. This section provides the top-level functional and performance requirements for the spacecraft.

3.1 System Requirements

3.1.1 Operational Epoch

The spacecraft shall be designed for an operational period that begins with the launch date as specified on the master schedule for the project.

3.1.2 Operational Lifetime

3.1.2.1 Minimum Lifetime

Following an initial period of in–orbit checkout, the operational lifetime of the spacecraft shall be a minimum of 5 years, with a goal of 10 years. Also see Section 3.1.5.3.

3.1.2.2 In-Orbit Checkout

The in-orbit checkout period for the observatory of up to 60 days is allocated as follows:

3.1.2.2.1 Spacecraft Checkout

The first phase of in-orbit checkout of up to 10 days is allocated to the spacecraft.

3.1.2.2.2 Instrument Checkout

The second phase of in-orbit checkout of up to 50 days is allocated to the science instruments, and to spacecraft calibration as provided in the checkout plan and approved by the Government.

3.1.3 End of Life Disposal

At the end of mission life, the method of disposal shall be by controlled reentry into the Earth's atmosphere for safe ocean disposal.

3.1.4 Orbit

The orbit altitude, inclination, and eccentricity shall be as specified in the Mission System Specification, 433-SPEC-0001, Section 3.3.1.4.

3.1.5 Reliability

3.1.5.1 Failures

3.1.5.1.1 Single Point Failures

Except for structural assemblies, including pressure vessels, no credible single point failure shall jeopardize the mission.

3.1.5.1.2 Two Credible Failures

No two credible failures shall cause loss of life or damage to surrounding facilities (transporters, launch pads, launch vehicle, etc.).

3.1.5.1.3 Failure Propagation

Failures shall not propagate to cause other failures.

3.1.5.2 Data Loss

The data loss allocated to spacecraft malfunctions occurring in the science data flow that prevent delivery of acquired data (without incurring safe mode) shall not exceed 0.1 % of mission science data over the operational life of the mission.

3.1.5.3 Reliability Allocation

Spacecraft reliability shall be at least 85 % with a goal of 90% at 5 years.

3.1.6 Availability

The total time spent in spacecraft outages that prevent acquisition of science data, i.e., those that result in safe mode, shall not exceed 1 % (TBR) of the operational life of the mission.

3.1.7 Coordinate Systems

The spacecraft shall use the inertial, body-fixed, and orbit-fixed coordinate systems defined in the Mission System Specification, 433-SPEC-0001, sections 3.3.1.6.1-3.3.1.6.3. The Spacecraft body-fixed coordinate system is coincident with the Observatory body-fixed coordinate system.

3.1.8 Units of Measurement

The spacecraft shall satisfy the requirement in the Mission System Specification, 433-SPEC-0001, Section 3.3.1.7.

3.1.9 Data Standards

3.1.9.1 CCSDS

The design of the spacecraft shall follow the recommendations of the Consultative Committee on Space Data Systems (CCSDS) for the transport of data.

3.1.9.2 Grade of Service

The spacecraft shall comply with CCSDS Grade of Service 2.

3.1.10 Spacecraft Mass

The mass of the spacecraft shall be as specified in the Mission System Specification, 433-SPEC-0001.

3.1.11 Mass and Power Reserves

Spacecraft mass and power reserves shall comply with ANSI, AIAA G-020-1992 Estimating and Budgeting Weight and Power Contingencies for Spacecraft Systems.

3.1.12 Pointing Knowledge Allocations

The spacecraft shall satisfy the pointing knowledge allocations specified in the Mission System Specification, 433-SPEC-0001, Section 3.3.1.11, for spacecraft attitude determination and system structural dynamics.

3.1.12.1 Attitude Determination Allocation

The spacecraft attitude determination allocation for both the LAT-SC system and the GBM-SC system shall include (but not necessarily be limited to):
1) Stability (knowledge) of each star tracker boresight with respect to the GNC reference surface(s), including contributions from thermal-mechanical and electronic sources.
2) GNC subsystem co-alignment calibration residuals.
3) Attitude determination filter performance, including:
a) Effects of star tracker noise and systematic errors (including star catalog errors and velocity aberration residual).
b) Effects of gyro bias and scale factor errors.

3.1.12.2 LAT Relative

In addition to items identified in 3.1.12.1, the spacecraft attitude determination allocation for the LAT-SC system shall also include (but not necessarily be limited to) the thermal-mechanical stability of the SC coordinate system (defined by the GNC alignment references) with respect to the LAT interface plane, as defined in the LAT IRD, 433-IRD-0001.

3.1.12.3 GBM Relative

In addition to items identified in 3.1.12.1, the spacecraft attitude determination allocation with respect to the system pointing knowledge error budget for the GBM-SC system shall also include (but not necessarily be limited to): CH-01
1) Thermal-mechanical stability of the SC coordinate system (defined by the GNC alignment references) with respect to the GBM interface planes. The term "GBM interface plane" is defined as SC to GBM NaI detector mechanical interface plane for an individual NaI detector. CH-01
2) One-g release and launch shift.

3.1.13 Environmental Requirements

3.1.13.1 Space Environments

The spacecraft shall be designed to meet all of its requirements over its required operational lifetime as specified in section 3.3.5.1 of the Mission System Specification, 433-SPEC-0001.

3.1.13.2 Launch Environment

The spacecraft shall survive the launch environment (vibration, pressure differentials, and temperature), as characterized in the Payload Planners Guide for the baseline launch vehicle that is specified in the Mission System Specification, 433-SPEC-0001, with no degradation to its operational capability or performance. The spacecraft shall survive the acoustics environment specified in section 3.2.5.2.

3.1.14 Spacecraft Operations

3.1.14.1 Nominal Operations

The spacecraft operations are described in the Operations Concept Document, 433-OPS-0001.

3.1.14.2 Safe Mode

3.1.14.2.1 Independent Mode

Safehold mode control shall be an independent GNC control mode.

3.1.14.2.1.1 Sensors and Actuators

No single sensor or actuator failure, which causes safehold entry shall compromise safehold safety.

3.1.14.2.1.2 Signal Paths

No single failure of any component shall impede communication between components used for safehold. In particular, if there are safehold components attached to a data bus, no single failure of a component attached to that data bus shall impede communication with any safehold component also on that data bus.

3.1.14.2.1.3 Control Laws and Utility Functions

3.1.14.2.1.3.1 Deleted CH-01

3.1.14.2.1.3.2 Data Outages

The safehold control laws shall accommodate temporary data outages from any single safehold sensor.

3.1.14.2.1.3.3 Failure Detection Logic

The safehold software shall accommodate all configurations of safehold sensors and actuators selectable by failure detection logic. Reconfiguration of safehold sensors or actuators while in safe mode is discouraged.

3.1.14.2.1.3.4 Math Exceptions

Safehold control laws and utilities shall be robust to isolated math exceptions.

3.1.14.2.1.4 Math Libraries and Hardware Drivers

Isolated errors (such as math exceptions) shall not hang up the safehold processor.

3.1.14.2.2 Autonomous Entry

Autonomous safe mode entry shall be capable of being enabled and disabled.

3.1.14.2.3 Ground Command

Safe mode shall be capable of being activated by ground command.

3.1.15 Autonomous Fault Protection System

The spacecraft shall perform autonomous on-board fault detection, isolation, and correction for critical functions where faults could cause damage, loss of control, or loss of science if not corrected immediately.

3.1.15.1 Fault Detection

The spacecraft shall continually monitor its critical functions during on-orbit operation for faults.

3.1.15.2 Fault Isolation

The spacecraft shall be designed to isolate faults to prevent propagation and to take corrective actions in case of critical faults.

3.1.15.3 Fault Correction

The spacecraft shall implement a hierarchical fault correction system to continue safe operation if possible, or to command safe mode entry if necessary.

3.1.15.4 Fault Notification

The spacecraft shall provide notification of all faults detected, isolated, or corrected in telemetry, and shall capture all relevant data necessary for anomaly analysis.

3.1.15.5 Spacecraft Monitoring

The spacecraft shall continuously monitor key parameters of the LAT and the GBM instruments and safe the instrument(s) if the out-of-limits condition satisfies a predefined criterion for safing.

3.1.15.6 Solar Array Monitoring

The onboard fault detection system shall monitor the solar array orientation, and shall command the observatory to enter Safe Mode if either solar array rotation angle is more than 30 degrees (TBR) from its commanded value over a 600 second (TBR) duration.

3.2 Mechanical Subsystem

The mechanical subsystem consists of all primary and secondary structure for the spacecraft bus, any necessary deployment assemblies and mechanisms, and interface structures between the spacecraft bus and the scientific instruments.

3.2.1 Bus Structure

3.2.1.1 Mounting Platform

The spacecraft bus structure shall provide a mounting platform for spacecraft bus components and for science instruments.

3.2.1.2 Constraints

The bus structure shall accommodate the location requirements of the bus components and the science instruments while meeting the launch vehicle constraints.

3.2.2 Center of Gravity Constraint

The center of gravity (CG) of the spacecraft bus when combined with that of the science instruments shall meet the observatory CG constraint as specified in the Payload Planners Guide for the baseline launch vehicle specified in the Mission System Specification, 433-SPEC-0001.

3.2.3 Envelope

The diameter of the spacecraft envelope in stowed configuration shall meet the fairing envelope constraint as specified in the Payload Planners Guide for the baseline launch vehicle specified in the Mission System Specification, 433-SPEC-0001.

3.2.4 Interfaces

3.2.4.1 Instrument Interfaces

The mechanical subsystem shall accommodate all instrument interface mechanical requirements as specified in the SC-instrument IRDs.

3.2.4.2 Field of View

The mechanical subsystem shall preserve the fields of view for science instruments as defined in the SC-instrument IRDs.

3.2.4.3 Alignment

The mechanical subsystem shall ensure alignment between the spacecraft coordinate system and the instrument coordinate systems as specified in the SC-instrument IRDs.

3.2.5 Structural Design Requirements

3.2.5.1 Observatory Stiffness

The fixed base stiffness of the observatory shall produce a first mode frequency greater than 35 Hz, axial, and greater than 12 Hz, lateral. CH-02

3.2.5.2 Acoustics

The acoustic spectrum for the Delta II 2920H-10 launch vehicle, supplied below, shall be used (TBR). (The Delta II 2920H-10 launch vehicle was formerly known as the Delta II 7920H-10 launch vehicle.)

This specification is intended to adequately envelope both the 2920-10 and 2920H-10 expected acoustic environments, so as such it is not a pure acoustic specification for either individual vehicle. It should be considered preliminary and is subject to changes, as the design of the GLAST observatory matures and the development and/or analysis of the 2920H vehicle continues.

Preliminary GLAST Acoustic Environment

One-third octave center frequency (Hz)	Acceptance test levels (dB)	Qualification test levels (dB)
31.5	121.4	124.4
40	125.5	128.5
50	128.5	131.5
63	131.0	134.0
80	133.0	136.0
100	132.5	135.5
125	132.0	135.0
160	130.5	133.5
200	131.5	134.5
250	132.5	135.5
315	131.5	134.5
400	128.0	131.0
500	125.0	128.0
630	122.0	125.0
800	120.0	123.0
1000	118.0	121.0
1250	117.5	120.5
1600	117.0	120.0
2000	116.7	119.7
2500	116.5	119.5
3150	116.5	119.5
4000	116.0	119.0
5000	114.5	117.5
6300	110.5	113.5
8000	106.5	109.5
10000	103.5	106.5
OASPL	**141.8**	**144.8**

Protoflight Levels = Qualification Levels

Test Duration = 60 seconds for acceptance and protoflight tests

Test Duration = 120 seconds for qualification (prototype) tests

3.3 Thermal Control Subsystem

The thermal control subsystem consists of all hardware necessary to control spacecraft bus temperatures within required temperature limits. The thermal control subsystem includes thermostats, heaters, two-phase heat transfer devices, heat straps, insulation, surface finishes and coatings, and radiating surfaces. The thermal control subsystem also includes temperature monitoring sensors and hardware required to satisfy LAT and GBM thermal interface requirements.

3.3.1 Component Temperatures

The thermal control subsystem shall maintain temperatures of spacecraft bus components within their allowable ranges.

3.3.2 Interfaces

The thermal control subsystem shall accommodate all instrument interface thermal requirements as specified in the SC-instrument IRDs.

3.3.3 Thermal Vacuum Test Compatibility

Two-phase heat transfer devices included in the spacecraft design shall be oriented consistent with instrument two-phase heat transfer devices so as to permit Observatory thermal subsystem verification testing.

3.4 Guidance Navigation and Control Subsystem

3.4.1 General Requirements

3.4.1.1 Pointing Control

The Guidance Navigation and Control subsystem (GNC) shall provide 3-axis stabilized pointing control for the observatory in all modes of operation.

3.4.1.2 Sky Referenced Pointing

Observatory pointing shall be sky referenced (J2000 coordinates) in both sky survey and pointed observation modes.

3.4.1.3 Momentum Management

The GNC subsystem shall meet its performance requirements while performing continuous momentum management.

3.4.1.4 Disturbances

The GNC subsystem shall meet its performance requirements while in the presence of any spacecraft-induced disturbances, including solar array disturbances.

3.4.1.5 Controlled Re-entry

The GNC subsystem shall provide attitude and orbit control to comply with controlled re-entry requirements identified in NSS 1740.14.

3.4.1.6 Stability Margins

The GNC implementation shall have stability margins of 12 dB in gain and 30 degrees in phase in all closed loop control modes.

3.4.2 Initial Acquisition

The GNC subsystem shall perform initial acquisition of power positive, thermally safe orientation such that the battery does not exceed 80% depth of discharge for 3σ tip-off rates as specified in the Payload Planners Guide for the baseline launch vehicle specified in the Mission System Specification, 433-SPEC-0001.

3.4.3 Safe Mode Support

3.4.3.1 Safe Mode Orientation

While in 'Safe Mode', the GNC subsystem shall provide a power-positive, thermally safe orientation for the observatory.

3.4.3.2 Sun Acquisition

On Safe Mode entry, the observatory shall acquire safe mode orientation from an arbitrary initial attitude, and maintain it there indefinitely.

3.4.4 Navigation/Orbit

3.4.4.1 Absolute Position Accuracy

The absolute accuracy for determination of orbit position in any direction (spherical error) shall be as specified in the Mission System Specification, 433-SPEC-0001.

3.4.4.2 GPS Dropouts

The above orbit determination accuracy shall be maintained through GPS dropouts of 30 minutes or less.

3.4.4.3 Orbital Elements Uploads

As a backup to using the on-board GPS inputs, the GNC subsystem shall accept spacecraft orbital elements uploads from the ground system.

3.4.5 Observation Modes

3.4.5.1 Yaw Steering

The observatory shall maintain the sun line within 1 degree, 3-sigma, of the spacecraft X-Z plane, on the +X side, in the observation modes. During yaw slew maneuvers and during repointing slews, the sun line may depart from the spacecraft X-Z plane, but the combined direct solar heat load absorbed by both LAT radiators due to these excursions may not exceed 27 watts when averaged over any one-orbit period. This requirement shall be verified by thermal analysis using the LAT reference radiators specified in section 3.2.3 of the LAT IRD, 433-IRD-0001. If necessary, the observatory +Z axis may CH-01 be off-pointed from its nominal sky survey pointing profile by up to 20 degrees, 3-sigma radial, during such slews in order to maintain the sun constraint.

3.4.5.2 Pointing Knowledge

Pointing knowledge shall remain within the knowledge allocation in section 3.1.12 during all slews of the observatory in its observation modes.

3.4.5.3 Agility

The spacecraft shall be capable of slewing the observatory +Z axis through an angle of 75 degrees in less than 10 minutes, with a goal of less than 5 minutes, while maintaining all applicable attitude constraints.

3.4.5.4 Sky Survey Mode

3.4.5.4.1 Orbit Fixed Referenced Pointing

The +Z axis of the observatory shall be commanded to point in a direction defined with respect to the orbit fixed frame defined in section 3.1.7. The rocking angle commands may be piecewise constant or may vary slowly (small multiples of orbit frequency) with time.

3.4.5.4.2 Rocking

Rocking angle offsets of the Z-axis shall range from -60 deg. to 60 deg.

3.4.5.4.3 Pointing Accuracy

The GNC subsystem shall maintain pointing of the observatory +Z-axis in the Sky Survey Mode within 2 degrees, 1 σ, radial with a goal of 0.5 degrees, 1 σ, radial, of its commanded direction.

3.4.5.5 Pointed Observation Mode

3.4.5.5.1 Earth Avoidance Angle CH-01

The Earth Avoidance Angle shall be a parameter that is adjustable on orbit.

3.4.5.5.2 Earth Avoidance Angle Initial Value

The initial value of the Earth Avoidance Angle shall be 30 degrees. CH-02

3.4.5.5.3 Earth Avoidance Constraint

The observatory shall not point the +Z observatory axis to within the Earth Avoidance Angle of any portion of the Earth, except during a repointing slew or by ground command. CH-01

3.4.5.5.4 Secondary Target Repointing

The GNC subsystem shall have the capability to slew and point to a secondary target (if previously identified) when the primary target is occulted by the Earth.

3.4.5.5.5 Primary Target Repointing CH-01

The GNC subsystem shall return from a secondary target to its primary target when the primary target is no longer occulted by the Earth.

3.4.5.5.6 Pointing Accuracy CH-01

The GNC subsystem shall maintain pointing of the observatory +Z axis in the Pointed Observation Mode within 2 degrees, 1 sigma, radial, with a goal of 0.5 degrees, 1 sigma radial, of its commanded pointing direction.

3.4.5.5.7 Target Within the Earth Avoidance Angle of the Earth

When the observation target is unocculted, but within the Earth Avoidance Angle of the Earth, the observation target shall be maintained within the Earth Avoidance Angle of the +Z Observatory axis. CH-01

3.4.5.5.8 Pointing Adjustment

When the observation target is occulted, or unocculted but within the Earth Avoidance Angle of the Earth, the commanded pointing direction shall be adjusted by the spacecraft to accommodate the Earth avoidance constraint. CH-01

3.5 Power Subsystem

The power subsystem shall supply electrical power to spacecraft equipment as required by the equipment and to the instruments as required by the LAT IRD, 433-IRD-0001 and the GBM IRD, 433-IRD-0002, and as allocated in the Mission Systems Specification, 433-SPEC-0001.

3.5.1 Battery

3.5.1.1 Nickel-Hydrogen Cells

The power subsystem shall use a battery or batteries consisting of Nickel-Hydrogen Individual Pressure Vessel (IPV) cells.

3.5.1.2 Depth of Discharge

The average depth of discharge of the battery, or each battery, shall be less than 30% of the nameplate capacity per orbit over the mission life.

3.5.1.3 Bypassing Cells

The power subsystem shall have the capability to electrically bypass battery cells that are performing poorly or that are failed on-orbit.

3.5.1.4 Ground Control of Bypassing Circuits

The battery bypassing circuit design shall include the capability to bypass individual battery cells within each battery pack via ground command. The spacecraft shall provide means to prevent inadvertent exercise of the command. CH-02

3.5.1.5 Battery Pressure Sensors

Battery pressure shall be measured through the use of strain gauges that shall be applied to a minimum of two (2) cells within each battery pack. CH-02

3.5.2 Power Distribution

3.5.2.1 Power Services

All power distribution services shall be redundant.

3.5.2.1.1 Science Instrument Service

The power subsystem shall supply power services to both the LAT and GBM instruments as specified in the SC-instrument IRDs. This service shall be provided using low impedance power buses implemented with multi-layer bus bars. CH-02

3.5.2.1.2 Spacecraft Services

3.5.2.1.2.1 Switched and Unswitched Power

The power distribution subsystem shall provide switched and unswitched power to spacecraft components as required by the components.

3.5.2.1.2.2 Deployment Bus

The power distribution subsystem shall provide a separate bus for deployment functions, i.e. explosive bolts, thermal release mechanisms, etc. The separate bus shall have arm, enable, and fire functions.

3.5.2.2 Grounding Configuration

The primary power system shall "ground" to the bus structure at a single point.

3.5.3 Power Subsystem Housekeeping Telemetry

The spacecraft shall telemeter sufficient data to identify and analyze power system faults.

3.6 Electrical Subsystem

3.6.1 Functional Requirements

3.6.1.1 Spacecraft Component Interconnect

The electrical subsystem shall provide the electrical interconnections of all flight equipment on the spacecraft.

3.6.1.2 Payload Interfaces

The electrical subsystem shall provide the electrical interface for the instruments as specified in the SC-instrument IRDs.

3.6.1.3 System Interfaces

The electrical subsystem shall provide the electrical interfaces between the spacecraft and the launch vehicle, ground support equipment, and test equipment.

3.6.1.4 Separation Events

The electrical subsystem shall detect separation events to initiate deployments and to power up spacecraft components.

3.6.2 Electromagnetic Compatibility

The contractor shall comply with the EMI Requirements Document for the GLAST Observatory, 433-RQMT-0005.

3.7 Command, Data Handling, and Telemetry Subsystem

3.7.1 System Requirements

3.7.1.1 On-board Communications

The C&DH subsystem shall use the Mil Std 1553B bus to provide on-board command, telemetry, and GBM to LAT communication services.

3.7.1.2 GRB Alert Messages

The C&DH subsystem shall generate GRB alert messages in all observation modes.

3.7.2 Commanding

All uplink commands shall comply with the CCSDS Telecommand Part 1: Channel Service document.

3.7.3 Data Handling

3.7.3.1 Data Acquisition

3.7.3.1.1 Science Data Interface

3.7.3.1.1.1 Instrument Packet Acquisition

The C&DH subsystem shall acquire science source data packets from the LAT and GBM instruments via a separate dedicated bus as defined in the SC-instrument IRDs.

3.7.3.1.1.2 Instrument Packet Storage

The C&DH subsystem shall input source data packets from the LAT and GBM science instruments to bulk storage at the rates specified in the SC-instrument IRDs.

3.7.3.1.2 Housekeeping Data

3.7.3.1.2.1 LAT Data

The C&DH subsystem shall acquire LAT instrument housekeeping data via the Mil Std 1553B bus.

3.7.3.1.2.2 GBM Data

The C&DH subsystem shall acquire GBM instrument housekeeping data via the Mil Std 1553B bus.

3.7.3.1.2.3 Spacecraft Data

The C&DH subsystem shall acquire spacecraft housekeeping data.

3.7.3.1.3 GPS Data

The C&DH subsystem shall acquire time, velocity, and position data from the GPS receiver.

3.7.3.2 Time Distribution

3.7.3.2.1 Pulse-per-Second

3.7.3.2.1.1 Signal Distribution

The C&DH subsystem shall distribute a pulse-per-second signal as defined in the SC-instrument IRDs.

3.7.3.2.1.2 Signal Accuracy

The C&DH subsystem pulse per second signal accuracy shall be as defined in the SC-instrument IRDs.

3.7.3.3 Bulk Storage

3.7.3.3.1 Data Storage Sizing

3.7.3.3.1.1 Science Data

The C&DH subsystem shall have the capacity to store up to 36 hours of science data at the rates and volumes specified in the SC-instrument IRDs.

3.7.3.3.1.2 Instrument Housekeeping Data

The C&DH subsystem shall have the capacity to store up to 36 hours of instrument housekeeping data.

3.7.3.3.1.3 Spacecraft Housekeeping Data

The C&DH subsystem shall have the capacity to store up to 36 hours of spacecraft housekeeping data.

3.7.3.3.2 Command Storage Memory Sizing

3.7.3.3.2.1 Instrument Command Storage

The C&DH subsystem shall provide storage for instrument commanding as specified in the SC-instrument IRDs.

3.7.3.3.2.2 Spacecraft Command Storage

The C&DH subsystem shall provide storage to support the stored command requirements for the spacecraft based on the operational observation profile section 3.9.7.

3.7.3.3.3 Simultaneous Operation

The C&DH subsystem shall provide simultaneous storage and playback of both science and housekeeping telemetry data.

3.7.3.3.4 Selective Retransmissions

The C&DH subsystem shall support selective re-transmissions of stored data.

3.7.4 Telemetry Downlink Format

All housekeeping downlink telemetry formats shall comply with the CCSDS Recommendation for Space Data Systems Standards, Telemetry Channel Coding document.

3.7.4.1 Encoding and Framing

The C&DH subsystem shall encode S-band downlink telemetry at the rates specified in the Mission System Specification, 433-SPEC-0001, Tables 1 & 2, using CCSDS forward error correction encoding and convolutional coding.

3.7.4.2 Output Rates

3.7.4.2.1 Bulk Storage Data

The C&DH subsystem shall output science data from bulk storage at the rates specified in the Mission System Specification, 433-SPEC-0001, Tables 1 and 2.

3.7.4.2.2 Real-Time Spacecraft Housekeeping Data

The C&DH subsystem shall output real-time spacecraft housekeeping at the rates specified in the Mission System Specification, 433-SPEC-0001, Tables 1 and 2.

3.7.4.2.3 Playback Spacecraft Housekeeping Data

The C&DH subsystem shall output playback spacecraft housekeeping at the rate specified in the Mission System Specification, 433-SPEC-0001, Table 1.

3.7.4.3 Virtual Channels

The C&DH subsystem shall implement CCSDS VCDU channel service.

3.8 Communications Subsystem

3.8.1 Ground Station Compatibility

The spacecraft communications subsystem shall be compatible with existing commercial ground stations, such as Universal Space Network (USN) in Hawaii, and the 6.1 meter antenna at Malindi, Kenya. CH-02

3.8.2 S-band Coverage

The S-band communications subsystem shall provide greater than 90% spherical coverage around the spacecraft, such that positive link margins are maintained at the data rates and frequencies specified in the Mission Systems Specification, 433-SPEC-0001, Tables, 1 and 2.

3.8.3 S-band Communications

3.8.3.1 TDRSS Compatibility

The spacecraft S-band communications subsystem shall be compatible with the TDRSS.

3.8.3.2 Data Rates

The communications subsystem shall ensure positive link margins for S-band communications at the data rates and frequencies specified in the Mission System Specification, 433-SPEC-0001, Tables 1 and 2.

3.8.4 X-band Communications

3.8.4.1 Direct Ground Transmission

The communications subsystem shall transmit X-band data directly to a ground station.

3.8.4.2 Ground Station Tracking

The X-band system shall support positive link margins for the science downlink for ground stations at up to 38° latitude from any observatory attitude in all science observation modes described in the Operation Concept Document 433-OPS-0001 Appendix A. CH-02

3.8.4.3 Bit Error Rate

The X-band transmit system shall ensure at least a 3 dB link margin with a maximum uncoded bit error rate of 1×10^{-5}.

3.8.4.4 Data Rate

The X-band data rate and frequency shall be as specified in the Mission System Specification, 433-SPEC-0001, Table 1.

3.8.4.5 Data Modulation

The communications subsystem shall provide Offset Quadrature Phase Shift Keying (OQPSK) modulation of the X-band data link. CH-02

3.8.5 Simultaneous Operation

The communications subsystem shall be capable of simultaneous operation of S-band and X-band communications.

3.8.6 Power Flux Density Requirements

The S-band and X-band power flux densities shall meet the NTIA Manual of Regulations and Procedures for Federal Radio Frequency Management, section 8.2.36 and annex B.

3.8.7 Spectrum Allocation

3.8.7.1 Compliance

The communications subsystem shall comply with national and international regulations, guidelines, and agreements for use of spectrum and bandwidth.

3.8.7.2 Deep Space Network

The GLAST system shall not interfere with the operation of the NASA Deep Space Network (DSN).

3.9 Flight Software

3.9.1 Command Processing

3.9.1.1 CCSDS Command Operation Procedures

The FSW subsystem shall support the CCSDS COP-1 validation and execution of real time commands.

3.9.1.2 Stored Commanding

The FSW subsystem shall load, store, schedule, and execute time-tagged commands and command sequences.

3.9.1.3 Downlink Support

The FSW subsystem shall support downlink transmissions, without affecting the collection of science data.

3.9.1.4 Object Uploads

The FSW subsystem shall support object (software and data) uploads to the instruments.

3.9.2 Telemetry Processing

3.9.2.1 CCSDS Packet Telemetry Functions

The FSW subsystem shall support the CCSDS Packet Telemetry Recommendations.

3.9.2.2 Health and Safety Monitoring

The FSW subsystem shall monitor critical health and safety parameters against established limits.

3.9.2.3 Corrective Action

The FSW subsystem shall take corrective action for time-critical faults that are detected based on ground modifiable rules stored onboard.

3.9.3 System Resources

3.9.3.1 Operating System

The FSW subsystem shall include a pre-emptive scheduling, multi-tasking Real-Time Operating System with an Application Programming Interface (API) and support for interrupt handling and device driver interfaces.

3.9.3.2 Device Drivers

The FSW subsystem shall provide all required device drivers.

3.9.3.3 Thermal and Power Management

The FSW subsystem shall provide thermal and power management as required.

3.9.4 Attitude and Orbit Determination and Control

The FSW subsystem shall support the orbit position and attitude determination and control requirements identified in section 3.4 - GNC

3.9.5 Observatory Modes

The FSW subsystem shall manage and control all mode and mode transitions.

3.9.6 1553 Message Interfaces

3.9.6.1 Ancillary Data

The FSW subsystem shall generate ancillary data messages for both the LAT and GBM instruments at the GNC attitude control loop update rate. Content requirements are documented in the SC-instrument IRDs.

3.9.6.2 Time

The FSW subsystem shall generate for distribution GPS Time messages correlated to the hard line pulse-per-second signal as documented in the SC-instrument IRDs.

3.9.6.3 Burst Alert Sequences

The FSW subsystem shall interact with the instruments in the Burst Alert processing sequences as defined in the SC-LAT ICD. CH-03

3.9.6.4 SAA Notification

The FSW subsystem shall notify the instruments of SAA entry and exit.

3.9.6.5 Instrument Notification

The FSW subsystem shall meet the warning time requirements specified in the SC-instrument IRDs before entering safe mode or removal of electrical power from the instruments.

3.9.7 Operations

3.9.7.1 Observation Sequences

3.9.7.1.1 Number of Mode Switches per Orbit

The spacecraft shall provide the means for executing up to 10 switches per orbit between Sky Survey and Pointed Observation control modes for a period of up to 168 hours. CH-03

3.9.7.1.2 Number of Distinct Pointed Observations per Orbit

The spacecraft shall provide for up to 5 pointed observations per orbit in different directions and durations for a period of up to 168 hours.

3.9.7.2 Sky Survey Profile

3.9.7.2.1 Sky Coverage

The spacecraft shall scan the LAT field of view (55 degree half-angle) over the full celestial sphere repetitively every 2 orbits.

3.9.7.2.2 Rocking

A stored command procedure shall execute a rocking profile, square or sinusoidal, for Sky Survey mode, using a maximum of 10 steps (TBR).

3.9.8 Safety and Fault Protection

3.9.8.1 Watchdog Timer

The FSW subsystem shall provide watchdog timer management and control.

3.9.8.2 Fault Protection

The FSW subsystem shall implement the fault protection requirement of Section 3.1.15 as appropriate.

3.9.9 Autonomy

3.9.9.1 Autonomous Repointing

The FSW subsystem shall be capable of repointing autonomously from either Sky Survey mode or Pointed Observation mode in response to LAT repointing requests.

3.9.9.2 "Go" or "No-Go" Decision Making

The FSW subsystem shall be capable of "go" or "no-go" decision making in response to any repointing request from the LAT.

3.9.9.3 Secondary Target

Secondary targets shall not be commanded during an autonomous repoint observation.

3.9.9.4 Additional Autonomous Repoint Requests

The FSW subsystem shall not repoint if additional autonomous repointing requests occur within an existing autonomous repointing operation.

3.9.9.5 Autonomous Repoint Duration

The FSW subsystem shall repoint for a predetermined duration that is controlled by a commandable parameter.

3.9.9.6 Autonomous Repoint Enable

The FSW subsystem shall not permit autonomous repointing unless enabled.

3.9.9.7 Automatic Resume

Upon completion of an autonomous repointing period, the FSW subsystem shall automatically resume the previously interrupted observation mode (sky survey or pointed observations).

3.9.10 TDRSS/Downlink Messages

3.9.10.1 Burst Alert Message

Upon receipt of a Burst Alert message from the GBM or LAT science instruments, the FSW subsystem shall format and initiate the transmission of a Burst Alert message within 1 second, either via TDRSS or the downlink (if during a GN contact).

3.9.10.2 Safe Mode Alert Message

Upon entry into Safe Mode, the FSW subsystem shall format and initiate transmission of a Safe Mode Alert message to the ground, either via TDRSS or the downlink (if during a GN contact).